Behavioral Risk Factors for Ski Injury: Problem Analysis as a Basis for Effective Health Education


ABSTRACT: A problem analysis dealing with the importance of behavioral risk factors for ski injuries is based on the results of a case-control study conducted among Dutch skiers. In this study, cases (N = 572) were a sample of those who filed insurance claims for medical costs incurred as the result of a ski injury that prevented them from skiing for more than one day. Controls (N = 576) were a sample of uninjured skiers who filed insurance claims for nonmedical reasons.

Not taking ski lessons appeared to be a risk factor among beginners (odds ratio [OR] = 2.5; etiologic fraction [EF] = 12%). Failure of bindings to release is associated with a higher risk (OR = 3.2) for lower extremity injury, indicating that optimal binding adjustment can have a substantial preventive effect. Surprisingly, binding adjustment in the Netherlands more often involved the use of a test device compared to the ski resorts involved. In the latter case, the injury risk was higher (OR = 1.6; EF = 17%). From our data and the available literature, it can be concluded that alcohol consumption is probably not an important risk factor for ski injury. Several findings from our study seem to indicate that risk underestimation may be a risk factor for ski injury, but further study is necessary on this point. Taken together, the empirical basis for behavioral risk factors other than those mentioned above is still rather weak and thus a restrictive policy with respect to health education for downhill skiers would seem appropriate.

KEY WORDS: downhill skiing, injury, etiology, health education, ski lessons, binding adjustment, alcohol, risk underestimation

Downhill skiing has been gaining enormous popularity in the Netherlands over the last few decades. Some 700,000 Dutch skiers actively participate in downhill skiing in other European countries (70% in Austria) for an average of about 10 days a year [1]. Unfortunately, skiing is not without risk. Some 2 to 4 injuries needing medical treatment occur every 1000 skier days [2,3]. Consequently, the annual number of Dutch casualties ranges from 14,000 to 28,000. Resulting medical costs are substantial, as well as the number of days of restriction from work and sports participation.

Prevention of ski injuries should be based on sound knowledge of the etiology of these injuries. Epidemiological studies that identify and quantify the contribution of putative risk factors by comparing injured and uninjured skiers are essential for this purpose [4]. Preventive factors can be divided into technical improvements in equipment and ski run, safety regulations, and individual behavior. This article, based on data on behavioral risk factors

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Health education aimed at prevention of ski injuries should concentrate on behavioral factors that contribute to the incidence of injury [4]. Systematic problem analysis of the available etiological evidence should form the basis of all health education intervention [5]. These behavioral factors must be able to be modified in the desired direction by means of health education. Whether this is possible can only be answered conclusively in a preventive trial in which behavioral modification is attempted, although a study of the determinants of the behavior at issue can be very helpful [5].

The importance of a behavioral risk factor actually consists of two dimensions. First, there is the strength of the association between the factor and the incidence of injury. This is preferably expressed as a relative risk (RR), which can be estimated by using the odds ratio (OR) from a case–control study [6]. Table 1 illustrates this for the instance of a dichotomous risk factor. Second, the prevalence of the risky behavior at issue among the population is also of consequence for the maximal potential benefits of health education. In a case–control study, the prevalence in the population can be substituted by the prevalence in the control group. Dangerous behavior (high OR) that is very rare (low prevalence) will therefore not necessarily be the best focus for health education.

Both dimensions of the importance of a risk factor can be unified by the calculation of the etiologic fraction (EF). This is the fraction (percentage) of injuries that could be avoided theoretically by complete elimination of the risky behavior at issue in the population for which the EF is calculated [6]. Table 1 illustrates the calculation of the etiologic fraction for the instance of a dichotomous risk factor from case–control data. As an approximation of the prevalence (among the population) of the risk factor at issue, the prevalence in the control group is taken.

This article presents a problem analysis of the behavioral risk factors for ski injuries based on results from a case–control study conducted among Dutch skiers [1]. First, the design of this study will be described briefly. Second, behavioral risk factors will be presented—ski lessons, binding adjustment, alcohol consumption, and risk underestimation. Third, the consequences for health education aimed at downhill skiers will be critically discussed.

**Methods**

Cases (injured skiers) and controls (uninjured skiers) during the 1984/1985 season were obtained from the records of a company covering roughly one third of the market for ski insurance in the Netherlands. Most Dutch skiers are insured. The cases selected were skiers

<table>
<thead>
<tr>
<th>RF₁</th>
<th>a</th>
<th>b</th>
</tr>
</thead>
<tbody>
<tr>
<td>RF₀</td>
<td>c</td>
<td>d</td>
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<table>
<thead>
<tr>
<th>I₁</th>
<th>I₀</th>
</tr>
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<tr>
<td>I₁/₁₀</td>
<td>OR = a/d, b/c</td>
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**TABLE 1—Measures of association relevant for the assessment of the importance of a behavioral risk factor from a case–control study.**

- RF₁ = risk factor present
- RF₀ = risk factor absent
- I₁ = injured
- I₀ = uninjured
- OR = odds ratio
- EF = etiologic fraction
- \(P₁\) = prevalence of risk factor
who had filed claims for medical costs as a result of a ski injury that made skiing or other activities impossible for more than one day. An equal number of uninjured skiers was chosen by taking the next claim from an uninjured skier received by the insurance company for other reasons, for example, loss or theft. A postal questionnaire was sent shortly after the ski holiday to the population thus defined.

Methods of data analysis (bivariate, stratified, and multivariate) performed in our study are described elsewhere [1]. The same holds for the response, the nonbehavioral risk factors, and the discussion of the general aspects of the validity of the study [1,7–9]. The present article focuses on our findings with respect to putative behavioral risk factors and relates them to the available literature. The strength of the association between a factor and injury risk will be estimated by calculating the odds ratio (OR; cross product ratio) [4,6]. An OR greater than one indicates that the factor is a risk factor indeed, while an OR between one and zero suggests a preventive effect. An OR equal to one will be found when an association is absent. The 95% confidence interval (CI) of the OR gives an impression of the imprecision of the point estimate. A 95% CI not including the null-value (OR = 1) is equivalent to a p-value smaller than 0.05 in a two-sided significance test. Besides OR and 95% CI, a global estimation of the etiologic fraction (EF) will be provided where appropriate (see Table 1 for the method of calculation).

**Behavioral Risk Factors**

*Ski Lessons*

Our data confirm the existing consensus [3,10] that beginners have twice the injury risk of intermediate or advanced skiers (OR = 2.1; CI = 1.5 to 2.9). Ski lessons are supposed to improve the skill of the skier and might thus reduce the injury risk for beginners especially. In the literature [3,11,12], no agreement is found on the overall safety effect of ski lessons. In our study, no overall effect of ski lessons was identified (OR = 1.0; CI = 0.8 to 1.4), although a protective effect was found among the subgroup of skiers who went only once or twice for a ski holiday (Table 2). For Dutch skiers, the number of ski holidays seems to be an acceptable measure of experience, because usually no skiing is done between these holidays (which last on average ten days [1]).

The small group (9%) of beginners who refrain from taking ski lessons have a substantially higher (2.5 times) risk compared to beginners who do take lessons. Consequently, this subgroup of beginners contrasts noticeably unfavorably with intermediate or advanced skiers.

<p>| TABLE 2—Adjusted percentages* and odds ratios* comparing skiers who had taken ski lessons to those who had not, stratified for experience.† |
|-------------------------------|-------------------------------|--------|</p>
<table>
<thead>
<tr>
<th>Injured, %</th>
<th>Not Injured, %</th>
<th>OR</th>
<th>CI</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FIRST OR SECOND SKI HOLIDAY (N = 157) (N = 132)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ski lessons</td>
<td>78</td>
<td>91</td>
<td>1.0</td>
</tr>
<tr>
<td>No ski lessons</td>
<td>22</td>
<td>9</td>
<td>2.5</td>
</tr>
<tr>
<td><strong>THIRD SKI HOLIDAY OR MORE (N = 366) (N = 432)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ski lessons</td>
<td>36</td>
<td>35</td>
<td>1.0</td>
</tr>
<tr>
<td>No ski lessons</td>
<td>64</td>
<td>65</td>
<td>0.9</td>
</tr>
</tbody>
</table>

*After direct standardization for age and gender.

*Weighted average over six strata for age and gender (Mantel-Haenszel) followed by a test-based 95% confidence interval (CI).

†Operationalized as the number of the current ski holiday.
(OR = 2.1 \cdot 2.5 = 5.3). Health education that persuades all Dutch beginners to take ski
lessons would possibly lower the incidence of injury among beginners by roughly 12% (EF
= 12%; this etiologic fraction can be calculated by using the formula from Table 1 and the
data from the upper part of Table 2: OR = 2.5 and \( P_1 = 0.09 \)). Some caution is warranted
in generalizing this to skiers of other countries, because Dutch beginners probably lack ski
experience completely, while, for instance, in alpine countries, beginners might already have
some basic skill in skiing. On the other hand, the prevalence of not taking lessons among
Dutch skiers is probably very low compared to beginners from other countries.

In contrast to what might be expected, we could not detect a protective effect of ski
lessons before the ski holiday (OR = 1.1; CI = 0.7 to 1.6). One fifth (19%) of
the Dutch skiers prepare by means of a course in ski gymnastics, but it would be premature
to advocate this as a risk-reducing measure.

**Binding Adjustment**

Ski bindings are constructed and individually adjusted to release when the forces on the
bones and ligaments of the lower extremities get dangerously high. Substantial improvements
have been made in this field within the last few decades [13–15]. The question is whether
binding adjustment is still an important risk factor. Binding release in our study was indeed
less frequent before lower extremity injury compared to other injuries (Table 3). The latter
percentage can be looked on as a rough estimation of binding release during a randomly
chosen fall among the control group, assuming that binding release has no bearing on the
origin of (isolated) nonlower extremity injury. Following the same line of reasoning, com-
pletely avoiding the failure of the bindings to release during a fall would reduce lower
extremity injury roughly by 22% among men and by 39% among women (etiologic fractions
calculated as explained above).

These etiologic fractions clearly form a theoretical and unrealistic maximum of the benefits
of health education achieving optimal adjustment for every skier. First, not all lower ext-
remity injuries can be considered (theoretically) preventable by a timely release of the
bindings. Johnson et al. [13] assume that the proportion of lower extremity equipment-
related (LEER) injuries among the lower extremity injuries is 80%. Second, optimal ad-

| TABLE 3—Adjusted percentages and odds ratios comparing the release of only one or no binding to the release of both bindings within the injured population, stratified for gender. |
|---------------------------------|-----------------|-----------------|------|------|
| Lower Extremity Injury, %       | Other Injuries Only, % | OR± | CI   |
| MALES (N = 136) (N = 129)       |                               |      |      |
| Both bindings released          | 30                            | 50   | 1.0  |
| One binding released           | 27                            | 23   | 2.1  | 1.0–4.1 |
| No release                     | 33                            | 13   | 3.2  | 1.6–6.5 |
| Unknown                        | 10                            | 13   |      |      |
| FEMALES (N = 204) (N = 103)    |                               |      |      |
| Both bindings released          | 18                            | 34   | 1.0  |
| One binding released           | 29                            | 22   | 2.7  | 1.3–5.7 |
| No release                     | 46                            | 28   | 3.3  | 1.7–6.5 |
| Unknown                        | 7                             | 17   |      |      |

±After direct standardization for age and gender.

±±Weighted average over six strata for age and gender (Mantel-Haenszel) followed by a test-based 95% confidence interval (CI).

±±±Odds ratios are given for the category at issues compared to the release of both bindings.
justment of the current ski bindings probably cannot prevent all LEER injury, because the design of the binding may cause it to release too late or not at all under certain circumstances [9]. From a recent German study [2], it appears that the bindings of uninjured skiers are adjusted on average 50% above the recommended setting of the binding release force, while the average deviation for the bindings of injured skiers with knee sprains is 85% and for tibia fractures even 150%. Hanft et al. [16] report that only the population suffering tibial shaft injuries as a result of bending and twisting has a distribution of release values that is substantially higher than the control population. Taken together, it seems that regular and adequate adjustment of ski bindings is indeed an important preventive measure on which health education should focus. However, knee injuries can probably not be prevented very effectively by adequate adjustment of ski bindings currently available.

Control of the right binding setting with a test device is widely advocated [17], but not always performed [18]. From our data it appears that two thirds of the ski shops in the Netherlands use such a device, while only one third of the shops at the ski resorts at issue actually test the binding setting. These observations are consistent with the fact that binding adjustment abroad at the ski resorts was associated with a 60% higher risk (OR = 1.6; CI = 1.2 to 2.2) compared to adjustment in the Netherlands [9]. Adjustment before traveling abroad could theoretically lower the incidence of injury among Dutch skiers by 17% (etiologic fraction based on OR = 1.6 and prevalence of adjustment at ski resort = 34%).

Alcohol Consumption

Alcohol consumption can increase the risks of skiing theoretically by both acute and long-term mechanisms. On the acute level, alcohol could influence reaction time, accuracy of movements, and the perception of risk [19,20]. The long-term effect may consist of a lowering of the intake of carbohydrates, thus hampering the glycogen resynthesis and thereby possibly increasing risk due to exhaustion and decreased movement control [21]. In contrast to what might be expected, perceptible blood or breath levels of alcohol are very rare both among injured and uninjured skiers [2,19,22]. Our study confirmed the relatively low prevalence of alcohol consumption during the breaks when skiing (Table 4). Those who did drink during the breaks took usually one or two drinks.

TABLE 4—Adjusted percentagesa and odds ratiosb for different levels of alcohol consumption compared to no consumption during the breaks and during the ski holiday.

<table>
<thead>
<tr>
<th></th>
<th>Injured, % (N = 572)</th>
<th>Not Injured, % (N = 576)</th>
<th>ORc</th>
<th>CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALCOHOL CONSUMPTION DURING BREAKS</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Never</td>
<td>79</td>
<td>67</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>Sometimes</td>
<td>18</td>
<td>28</td>
<td>0.6</td>
<td>0.4–0.8</td>
</tr>
<tr>
<td>Every day</td>
<td>3</td>
<td>6</td>
<td>0.5</td>
<td>0.3–0.9</td>
</tr>
<tr>
<td>DAILY AVERAGE ALCOHOL CONSUMPTIONd</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 consumptions</td>
<td>28</td>
<td>22</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>1 or 2 consumptions</td>
<td>33</td>
<td>31</td>
<td>0.8</td>
<td>0.5–1.1</td>
</tr>
<tr>
<td>3 or 4 consumptions</td>
<td>25</td>
<td>23</td>
<td>0.8</td>
<td>0.5–1.1</td>
</tr>
<tr>
<td>5 or more consumptions</td>
<td>15</td>
<td>23</td>
<td>0.5</td>
<td>0.3–0.7</td>
</tr>
</tbody>
</table>

aAfter direct standardization for age and gender.
bWeighted average over six strata for age and gender (Mantel-Haenszel) followed by a test-based 95% confidence interval (CI).
cOdds ratios are given for the category at issue compared to the first category ("never" and "0 consumptions," respectively).
dExpressed in standard glasses containing the same amount of alcohol for all alcohol beverages.
Surprisingly, it appears that alcohol consumption during breaks protects against injury. The same appeared to hold for the average daily consumption during the ski holiday (Table 4). Elsewhere [1] it was argued that this apparent acute and long-term protection by alcohol was not to be considered as causal. Our findings could originate (partly) from selective underreporting by injured skiers or in differences in personality between teetotalers and other skiers. Therefore, the etiologic fraction for converting teetotalers must be considered meaningless and is not calculated for this reason. Our overall impression is that alcohol is neither a substantial risk factor nor a protective factor for ski injury.

Risk Underestimation

Individual risk-taking behavior could be an important determinant of ski injury. Excesses in risk taking (relative to the circumstances and the skill of the skier) could be due to a sensation-seeking tendency or to risk underestimation. Although often mentioned in the popular literature [22] on downhill skiing, these factors are very difficult to operationalize. In a second study [23] among the respondents of our original case–control study, we used the Sensation-Seeking Scale [24] for this purpose. Skiers appeared to score relatively high on this scale, especially on the subscale indicating a desire to engage in risky activities. But contrary to what might be expected, injured skiers appeared to have a lower score on this personality trait than uninjured skiers [23].

Besides the possibility that the Sensation-Seeking Scale offers no valid operationalization of the risk-taking behavior of skiers, there seems to be the alternative explanation that underestimation of the actual risks is the crucial factor. Sensation seekers could be relatively skilled in assessing risks and performing at the limit of their individual capacities. In this perception, especially the skiers who underestimate the risk of certain situations or activities are at risk. This explanation finds some support in our result that skiers who reported that they had been rather afraid of having an accident leading to injury before their holiday, appeared to have a 40% lower injury risk (Table 5). Assuming that this mild fear represents a realistic assessment of the risks of skiing, health education focused on this point may decrease the incidence of injury (as indicated by the etiologic fraction) by a maximum of 35%. Of course, this is only a very tentative conclusion and further studies on the role of risk underestimation are needed before health education intervention can be reasonably based on this idea. Additional support for the role of risk underestimation comes from the general finding [8,19,25] that the injury risk is higher under favorable circumstances (cloudless, not cold, and good visibility).

Health Education for Skiers

In both our study and other studies mentioned above, the odds ratios calculated do not necessarily point to causality and may suffer from major or minor biases for a number of reasons [1]. For most variables, more precise measurement would be better, for example, binding adjustment, while sometimes external sources of data would seem to be preferable, for example, recklessness. Furthermore, a prospective instead of the usual retrospective design would be more informative about the effects of some factors, for example, physical condition. All doubts about the causal interpretation of the odds ratios have consequences for the interpretation of the etiologic fractions as well. Furthermore, the etiologic fractions are based on the debatable assumption that the prevalence of the behavioral risk factor among the control group is the same as in the population considered for the health education intervention. Because elimination of the risk factor at issue usually will not be total, the real effect on the incidence of injury will be considerably smaller than the etiologic fraction.
TABLE 5—Adjusted percentages and odds ratios for fearing an accident compared to not being afraid before the ski holiday.

<table>
<thead>
<tr>
<th></th>
<th>Injured, % (N = 572)</th>
<th>Not Injured, % (N = 576)</th>
<th>OR</th>
<th>CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not afraid</td>
<td>87</td>
<td>80</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>Slightly afraid</td>
<td>13</td>
<td>19</td>
<td>0.6</td>
<td>0.4–0.8</td>
</tr>
<tr>
<td>Very afraid</td>
<td>0</td>
<td>1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*aAfter direct standardization for age and gender.

*bWeighted average over six strata for age and gender (Mantel-Haenszel) followed by a test-based 95% confidence interval (CI).

indicates. Addition of etiologic fractions is still a rather common mistake [6]. Risk factors are often strongly associated and act together in the causation of a ski injury. Summation of etiologic fractions would start from the unrealistic assumption that the risk factors at issue act completely independently of one another [6]. Also, the external validity of the data presented above can be questioned. Dutch skiers differ substantially from skiers in, for instance, alpine countries, which may hamper the generalizability of our data.

Let us assume that the problem analysis has yielded valid knowledge on the importance of some behavioral risk factors. This would only be a first step toward effective health education [5]. Further research would be necessary to study the determinants of the behavior at issue, so that the design of the intervention can be made optimal. The next step would be the execution of a preventive trial in which behavioral change and the reduction of the incidence of injury can be assumed [15]. Until now, only the optimal adjustment of ski bindings has been investigated in such a preventive trial [26].

Taken together, the empirical basis for the importance of most putative behavioral risk factors for ski injury is still rather weak. Exceptions to this rule are inadequate binding adjustment, the failure of beginners to take ski lessons and, to a lesser extent, underestimation of the actual risks. As far as the many other putative behavioral risk factors are concerned, we feel that a very restrictive policy with respect to health education is appropriate. We do not agree with the habit of smothering the skiers in an avalanche of well-meant preventive remarks; we think that effective prevention is impossible if education is handled in such a loose, aspecific way. Furthermore, we do not like the idea that some skiers might feel guilty about certain aspects of their behavior, for example, moderate alcohol consumption, prematurely decreed as being dangerous by health educators.

References


